CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-219

OAK RIDGE AND RELATED FAULTS VICINITY OF FILLMORE AND SANTA PAULA
Ventura County, California

by
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INTRODUCTION

The Oak Ridge fault zone is an east to northeast trending zone of south-dipping reverse faults which extends inland from the Oxnard plain and along the south margin of the Santa Clara River (Figure 1). It was previously the subject of Fault Evaluation Report 54 (Smith, 1977). More recent studies on this fault zone have been made by Robert Yeats and his students at Ohio University and Oregon State University. Yeats (1988) pointed out that the Oak Ridge fault zone marks the southern boundary of the Ventura trough, which extends for more than 100 km from the Santa Barbara Channel eastward to the Santa Susana Mountains. This report will review and evaluate some of the recent observations of Yeats and other workers on the Santa Paula and Moorpark 7.5-minute quadrangles, and in particular assess a short splay of the fault near the Bardsdale Cemetery (Figure 2). This previously unnamed fault splay, referred to here as the Bardsdale Cemetery fault, has geomorphic expression and was recently the subject of a trench study performed under a USGS National Earthquake Hazards Reduction Program grant (Powell and others, 1987; Yeats, 1988). The purpose of this fault evaluation report is to determine if parts of the Oak Ridge fault zone in the vicinity of Fillmore and Santa Paula are sufficiently active and well defined to be included in a Special Studies Zone under the Alquist-Priolo Special Studies Zone Act of 1972 (Hart, 1988).

not referenced

SUMMARY OF AVAILABLE DATA

Earlier work on the Oak Ridge fault was summarized by Smith (1977). This earlier body of work, typified by Weber and others (1975), mapped the fault as largely concealed by Santa Clara River alluvium and landslides (Figures 1 and 2). Most of what was known about the fault came from subsurface data. Surface exposures are few and the fault location was commonly inferred from features such as faceted spurs at the edge of the river alluvium.

Subsequent work has looked at the tectonic framework surrounding the fault zone (Yeats and others, 1988) and at evidence of late Quaternary deformation and displacement (Hall, 1982; Yeats and others, 1982; Yeats and Gardner, 1986 & 1988; Powell and others, 1987; Yeats and others, 1986). Yeats (1988) divides the fault zone into five segments: 1) a west-trending coastal and offshore segment, 2) a northeast-trending oblique-slip segment that marks the west end of Oak Ridge, 3) an east-trending dip-slip segment with "tectonic topography east of Santa Paula", 4) a lobate dip-slip segment from Balcom Canyon to Wiley Canyon, and 5) "an eastern segment where the fault divides into several splays and dies out". Yeats (1988) as well as Weber and others (1975) plotted their fault data at a scale of 1:48,000. This fault evaluation report will address features in adjacent parts of segments 3 and 4 on the Moorpark and Santa Paula 7.5 minute quadrangles.

Yeats and others (1981) observe that near the coast the Oak Ridge fault "does not cut strata shallower than 1,250 to 1,500 m below the surface," although late Pleistocene sediments are deformed into two en echelon pressure ridges at Montalvo. They interpret some small faults at the "Montalvo Mounds" as related minor displacements which are not connected to the Oak Ridge fault at depth. One of these faults displaces deposits which are inferred to be younger than 30,000 years. They conclude that displacement on the Oak Ridge fault does not present a ground-rupture hazard in this area but can produce seismic shaking. Yeats and others (1988) propose that displacement west of Saticoy is transferred from the south-dipping Oak Ridge fault to what they call the Sisar decollement, a structure which reaches the surface as folding and several south-dipping faults on the north side of the Ventura River.

Yerkes and Lee (1987) mention that the fault creates a groundwater barrier near Saticoy. Between Saticoy and Santa Paula the fault would probably be visible at the surface except that it has been obscured by fluvial processes in the Santa Clara River. East of Santa Paula but west of Balcom Canyon (Figure 2) the fault offsets an older landslide deposit, but does not cut younger stream terraces (Yeats, 1988). Weber and others (1975) show this fault as well as another possible fault along the north margin of the landslide (Figure 2). Another old landslide east of Balcom canyon was also shown to be possibly offset (Weber and others, 1975). A concealed trace of the fault northeast from Balcom Canyon, shown by Yeats (1988) is based on interpretation of well data by Rieser (1976).

At Bardsdale a splay of the Oak Ridge fault, the Bardsdale Cemetery fault, appears to reach the surface through late Pleistocene and Holocene fan deposits. The fault, which is expressed as a 5 meter scarp through the Bardsdale Cemetery, was first reported by Yeats and others (1982). According to Yeats and Gardner (1986) this scarp, which they referred to as the Bardsdale Cemetery scarp, overlies a north-dipping normal fault which is south of the main trace of the Oak Ridge fault. They felt the fault was "clearly a subsidiary of the Oak Ridge fault". At the Bardsdale Cemetery a trench was excavated across the scarp which exposed faulted Quaternary alluvial fan deposits which were radiocarbon dated at 2010±145 ybp (Yeats and others, 1986). Yeats (1988) described from 1.7 to 2.1 meters of vertical separation of the Holocene fan deposits. The fault, as exposed in the trench, strikes N70°E and dips 60°-65°N. Yeats (1988) believes the trench exposure and scarp may provide evidence for as many as three events in the past 2000 years. He interprets the discrepancy between the bed offsets (1.7m-2.1m) and the scarp height (5m) as being the result of warping over a deeper low angle reverse fault which does not reach the surface, with the observed normal faulting resulting from bending moment in the upwarp. The normal fault is overlain by unfaulted but warped sediments. A log of the trench is included as Figure 3. Yeats' (1988) model is shown in Figure 4.

Further east, along the south side of the Santa Clara River between Fillmore and Piru, Weber and others (1975) observed several areas where the abrupt mountain front may mark the location of additional fault segments. Yeats (1988) also discussed part of the area south of Piru, referring to the "Camulos scarp", and indicated that it was ambiguous whether this was a tectonic or an erosional feature.

The Oak Ridge fault is interpreted to have been active in Pliocene time with activity continuing into the Pleistocene (Yerkes and others, 1987). Yeats (1988) interprets a late-Quaternary slip-rate, east of Saticoy, of 5.9 to 12.5 mm/yr with a recurrence interval of 250 to 500 years. Slip rates were based on maximum vertical separations of horizons measured from their elevation in the crest of the Oak Ridge anticline to the same horizon in the trough of the Santa Clara syncline. The high end of the slip-rate range was based on a young age of 0.2Ma for the top of the Saugus formation. There are uncertainties in this age and an age of 0.4Ma is perhaps better documented (see discussion in Yeats, 1988).

SEISMICITY

Seismicity along the Oak Ridge fault zone has not been very notable (Figure 5). Yerkes and Lee (1987) note a magnitude 2.5 earthquake in 1971 which had a fault plane solution which might be associated with the Oak Ridge fault. In the vicinity of the Bardsdale Cemetery fault, specifically, no epicenters were noted by them or by the California Institute of Technology (1985).

AERIAL PHOTO INTERPRETATION

Review of 1952 aerial photographs confirms the presence and location of the Bardsdale Cemetery scarp. Photo-interpretive data were plotted on Figure 2 using a Bausch & Lomb Stereo Zoom Transfer Scope. In the 1945 Fairchild photos a rather sharp scarp at the base of the more subdued main scarp is visible in the orchard for a distance of approximately 900 feet (≈275m). The 1945 photos also show a slightly different eastern extension of the feature onto the Grimes Canyon fan than in the 1952 photos. Northwest-trending vegetation lineaments are probably related to drainage. Due to the long history of agriculture and human occupation in the area, other possible features indicative of recent faulting are not observable. About one half mile to the east, past Grimes Canyon Road, lies another scarp which is roughly on trend with the Bardsdale Cemetery scarp. It is a possible continuation of the scarp, with the intervening section having been obscured by the Grimes Canyon fan. Because of the linearity, orientation and relatively uniform height of these scarps they seem more likely to be fault related than erosional.

A much subtler scarp to the north, between Bardsdale Avenue and Riverside Avenue, shows up on the 1953 photos and on the 1988 photos. In the 1953 photos the feature shows up as tonal and height discontinuities within orchards, which reflect ground elevation differences. Surface elevation differences along the somewhat sinuous feature are more apparent in the 1988 photos. Although differently oriented, the scarp may align with a much more pronounced scarp to the east and may be merely the continuation of this apparent river bank which has also been masked in the intervening area by the Grimes Canyon fan.

About one mile west of the Bardsdale Cemetery scarp is another, shorter (2000'), north-facing scarp. The mid-portion of this scarp is well defined but gentler than the Bardsdale Cemetery scarp. At its eastern end several small gullies appear to have incised upslope from the scarp. At its western end the scarp fades into a tonal anomaly in the air photos. A slightly darker, irregular area immediately north of this anomaly may be wetter ground suggesting a locally depressed area.

A large landslide west of Balcom Canyon (Figure 2, blue landslide) predates both the modern Santa Clara River floodplain (elevation 300'-320') and an earlier elevated surface (elevation 360'-380'). The landslide was initially faulted prior to development of either of these surfaces. The fault displacement has resulted from dominantly vertical offset (north side down) now totalling almost 200 feet with an undetermined amount of prior offset. The toe of a subsidiary landslide (Figure 2, lavender), nested within the larger one, may be faulted as suggested by a small sidehill bench. The toe of another landslide to the west may also be faulted where a break-in-slope was noted. This inferred faulting may post-date the older elevated (360'-380') surface. More clearly post-dating this surface is a possible fault (Weber and others, 1975) truncating the north margin of the landslide (along South Mountain Road), however this scarp may be caused or enhanced by erosion. Another possibly faulted landslide (according to Weber and others, 1975) east of Balcom Canyon appears to be older, with no fresh looking features.

Several other scarp-like features, from Santa Paula to Piru (beyond the boundaries of Figure 2), were looked at in the aerial photographs. These are considered to be stream cut or stream modified features which cannot be unambiguously attributed in any degree to faulting. Most exhibit the variable scarp height across fans that would be expected of an erosional scarp.

FIELD OBSERVATIONS

The Bardsdale Cemetery scarp as well as the subtler short scarp observed to the north were inspected in the field on August 29, 1990. Most of the Bardsdale Cemetery scarp was verifiable as an obvious elevation change between two gentler surfaces, but many years of citrus production have modified the scarp so that none of the original landform is preserved. Part of the scarp to the north was likewise verified, but could not now be differentiated, without trenching, from a stream cut bank.

DISCUSSION AND CONCLUSIONS

The Bardsdale Cemetery scarp is clearly identifiable in the aerial photos and corresponds both in location and trend with the Holocene fault which is identified in a trench excavated across the scarp (Yeats and others, 1986; Yeats, 1988). The suggestion by Yeats (1988) that there may be an underlying low angle reverse fault below trench depth is reasonable for a couple of reasons: the surface deformation exceeds the observed fault displacement, and the observed fault location (in the trench) is more than half way up the scarp. Although the normal fault did not reach the surface in the trench, the sharp, nearly vertical scarp at the base of the main scarp immediately north of the cemetery (visible in the 1945 air photos) may be a local surface trace of this fault or Yeats' proposed low angle fault. Yeats' interpretation of these faults as shallow bending-moment faults (Figure 4) implies that the Bardsdale Cemetery fault may have a surface rupture potential but may not, itself, be a strong seismic source. It seems likely that this fault would move in conjunction with activity on the Oak Ridge fault.

The scarp to the east of Grimes Canyon Road, although not as sharp as the Bardsdale Cemetery scarp, has the same orientation and has a comparable height. If these scarps are in large part a result of folding, then the more subdued nature of the eastern scarp may mean that faulting, if present, is not as close to the surface as at the Bardsdale Cemetery. On the other hand, the relatively abrupt toe of the slope (in comparison to the top of the slope) suggests that recent surface faulting may have occurred.

The subtle scarp one mile north of the Bardsdale Cemetery scarp may be an expression of the Oak Ridge fault, as suggested by its sinuosity, location and orientation. Its trend and expression are different enough from the more obviously erosional scarp to the east to imply a different origin. The Oak Ridge fault was projected in this area by Yeats (1988) who cited Rieser's (1976) interpretation of subsurface data. Further to the southwest, along Yeats'(1988) inferred location of the Oak Ridge fault, is another, better defined, scarp with visible effects on local drainage. Together these two features may represent surface displacement along the Oak Ridge fault.

Although several other features along the main trace of the Oak Ridge fault are well-defined they are not clearly sufficiently active (i.e. Holocene) to warrant zoning under the Alquist-Priolo Special Studies Zone Act (see Hart, 1988). There are numerous scarp-like banks in the flood plain which are indistinguishable from cut banks. The faulted landslide west of Bardsdale does not show any clearly Holocene expression and its toe, if faulted, may be buried by Santa Clara River alluvium. Subsequent subsidiary landslides may also be faulted and these might be Holocene, however this cannot be proven without additional detailed studies. Yeats' (1988) segmentation of the fault zone at Balcom Canyon provides a basis for **not** assuming that this part of the fault zone is as active as the segment near Bardsdale.

The deformation at the Montalvo Mounds, although clearly late Pleistocene in age, cannot be shown to be Holocene.

RECOMMENDATIONS

Based on the documented Holocene displacement in the trench at the Bardsdale Cemetery (Yeats, 1988) the Bardsdale Cemetery fault is Holocene active. Based on the well-defined scarp identifiable in the 1945 and 1952/1953 aerial photos the fault is well-defined. Several common traits link the well-defined scarp east of Grimes Canyon to the Bardsdale Cemetery scarp. The scarps to the west and to the north are well-defined and probably Holocene; their orientation, morphology, and location along the inferred trace of the Oak Ridge fault suggest that they are indeed an expression of this fault.

I recommend zoning the Bardsdale Cemetery fault and the inferred fault along trend east of Grimes Canyon as delineated on Figure 2. I also recommend zoning the two highlighted scarps along the Oak Ridge fault to the north and west of the Bardsdale Cemetery. I do not recommend zoning any other parts of the main trace of the Oak Ridge fault at this time as the fault is not well defined along most of its surface trace and, where it is reasonably well defined (such as west of Balcom Canyon and near Piru) it has not yet been shown to be clearly Holocene. Any future studies along the main trace, particularly at the faulted landslide near Balcom Canyon, should be watched for evidence of Holocene displacement.

Reviewed and approved.
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AERIAL PHOTOGRAPHS USED

Fairchild Aerial Surveys (FAS)			1"=2000'	B/W	9x9
4/23/45	Flight 9460	frames 10 to 13			
Pacific Western Aerial Surveys (PWAS)			1'=2000'	color	9x9
11/16/88	PW-VEN 6-183 to 6-190				
11/22/88	PW-VEN 6-191 to 6-193				
11/22/88	PW-VEN 6-225 to 6-229				
U.S.Department of Agriculture (USDA)			1:20,000	B/W	9x9
12/13/52	AXI-1K-45	to -47, and -70 to -73			
12/23/52	AXI-2K-82	to -85			
1/ 3/53	AXI-3K-46	to -48, and -94 to -96			
10/19/53	AXI-11K-11	to -12			
11/16/53	AXI-11K-133	to -136			
U.S.Geological Survey (USGS)			1:30,000	B/W	9x9
8/13/67	GS-VBUK	frames 1-110 to 1-112			

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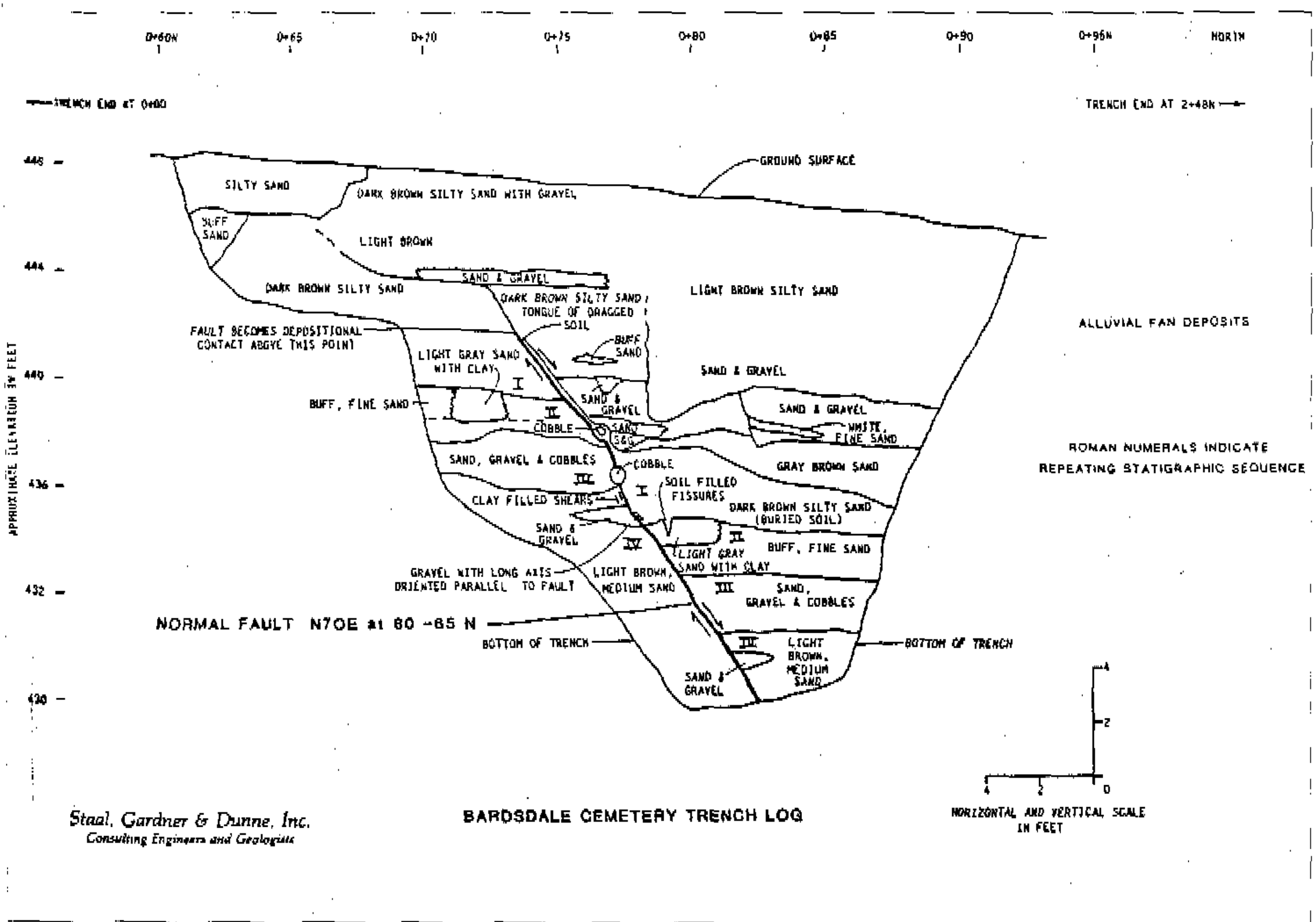

Figure 3 (FER-219) - Log of part of a trench across the Bardsdale Cemetery scarp. The fault exposed is a splay of the Oak Ridge fault. Holocene radiocarbon date obtained from unit I. (From Yeats and Gardner, 1986). Trench location shown on Figure 2.

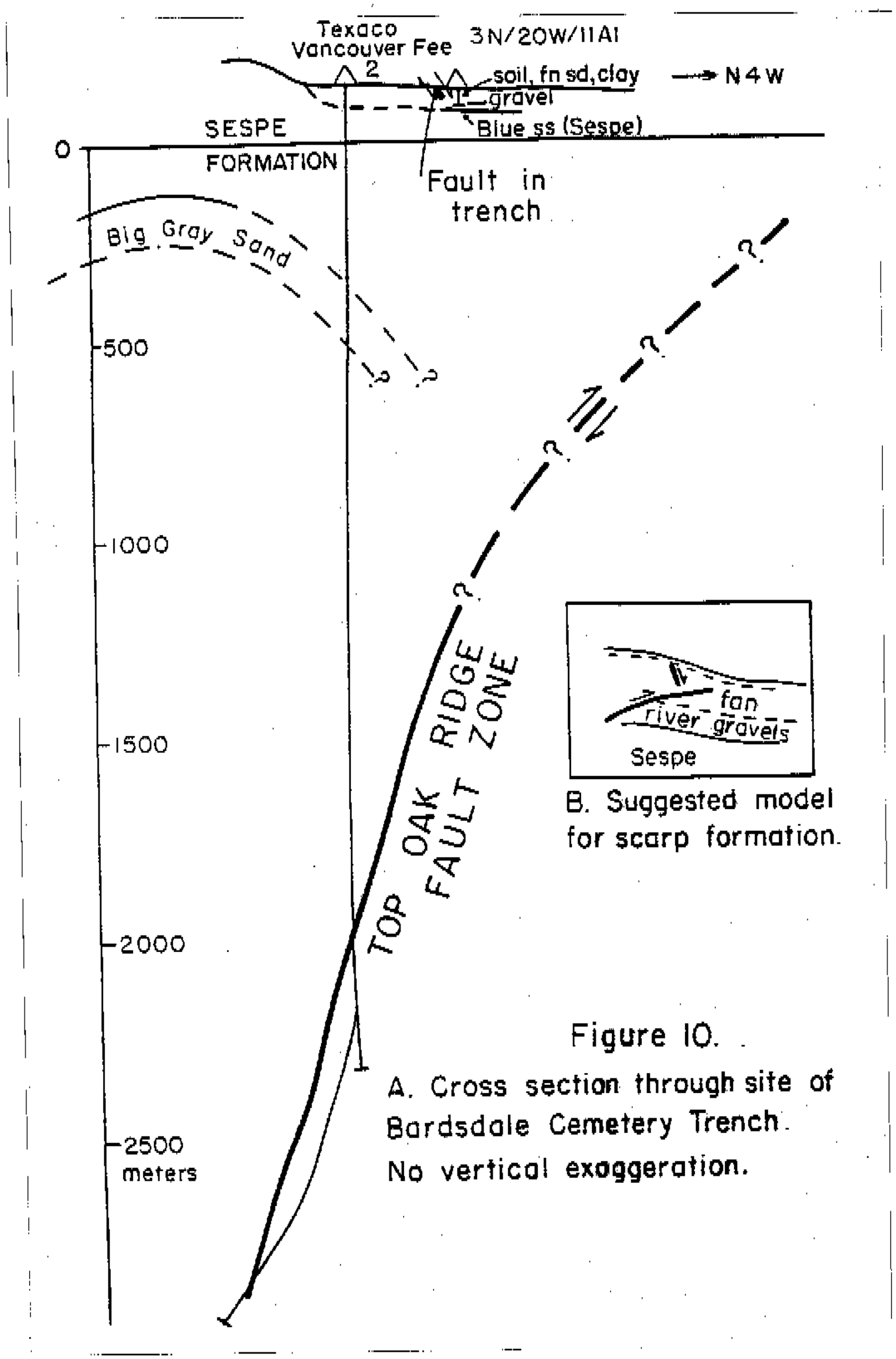

Figure 4 (FER-219) - Model explaining the relationship of the Bardsdale Cemetery scarp to the fault exposed in the trench (Figure 3) and to the Oak Ridge fault. (From Yeats, 1988, figure 10).